DRAFT 8/16/99

PPIHWG Report on 25.903(e) – Inflight Starting

1. What is the underlying safety issue addressed by FAR/JAR? *[*Explain the underlying safety rationale for the requirement. Why does the requirement exist?*]*

The total loss of all propulsive power, malfunction of all engines installed on an airplane, for environmental, human error and other causes has occurred. The actual capability to inflight restart one or more engines, after all engine flameout or are shutdown, has provided the capability to avoid forced landings and the potential for severe consequences. However, engine certification standards are silent on a requirement to demonstrate a minimum inflight engine re-starting capability. The airplane certification requirements, whilst requiring that an inflight re-starting capability be demonstrated, do not establish a minimum standard for the required capability in terms of altitude, altitude loss and airspeed range given all engines have been lost. Lack of an explicitly defined inflight re-starting minimum safety standard has resulted in wide variation in the inflight engine re-starting capabilities. Some turbine engine types have no inflight windmilling re-starting capability at all and alternate means for inflight re-starting have been required under special condition. This regulatory proposal present in this Report is to amend the regulation to clearly address the all engine out failure condition and provide a minimum inflight re-starting capability to be achieved and a means to demonstrate compliance by the addition of a new rule and associated advisory material.

2. What are the current FAR and JAR standards? [*Reproduce the FAR and JAR rules text as indicated below.*]

"FAR part 25.903(e)
Restarting capability. (1) Means to restart any engine in flight must be provided (2) An altitude and airspeed envelope must be established for in-flight engine restarting, and each engine must have a restart capability within that envelope. (3) For turbine engines powered airplanes, if the minimum windmilling speed of the engine following the inflight shutdown of all engines, is insufficient to provide the necessary electrical power for engine ignition, a power source independent of the engine-driven electrical power generating system must be provided to permit in-flight engine ignition for restarting."

JAR 25.903(e) is identical to the FAR wording except for a reference to ACJ 25.903(e)(2) in the second subparagraph.

This Report proposes to adds a new 25.903(e)(4) requirement and associated Advisory Material.

3. What are the differences in the standards and what do these differences result in? [*Explain the differences in the standards, and what the differences result in relative to (as applicable) design features/capability, safety margins, cost, stringency, etc.*]

The are no differences in the stated standard as shown in #2 above. Both standards do not adequately describe the minimum inflight restarting envelope of airspeed and altitude standard to be demonstrated given an all engines out situation (and no capability to use starter assist using pneumatic power from other engines on the airplane). Further the current standards to not provide a performance standard to be achieved with respect to altitude loss during the inflight re-start.

4. What, if any, are the differences in the means of compliance? [*Provide a brief explanation of any differences in the compliance criteria or methodology, including any differences in either criteria, methodology, or application that result in a difference in stringency between the standards.*]

A proposed means of compliance is provided in the associated Proposed AC.

5. What is the proposed action? [*Is the proposed action to harmonize on one of the two standards, a mixture of the two standards, propose a new standard, or to take some other action? Explain what action is being proposed (not the regulatory text, but the underlying rationale) and why that direction was chosen.*]

The proposed action is to establish a new rule and means of compliance which directly deal with the safety concern.

6. What should the harmonized standard be? [*Insert the proposed Text of the harmonized standard here.*]

See attachments – draft NPRM, rule and advisory material.

7. How does this proposed standard address the underlying safety issues (identified under #1? [*Explain how the proposed standard ensures that the underlying safety issue is taken care of.*]

The proposed rule requires that the "all engine out failure conditions" be addressed under four critical conditions likely to be encountered in service. Performance based success criteria concerning altitude loss during inflight re-starting is described. Additionally, the entry conditions for each in-flight restarting demonstration are defined. Given the airplane is demonstrated to have this engine restarting capability the safety objective, of minimizing the hazard associated with all engine out conditions, will be achieved

8. Relative to the current FAR, does the proposal increase, decrease or maintain the same level of safety? Explain. [*Explain how each element of the proposed change to the standard affects the level of safety relative to the FAR. It is possible that some portions of the proposal may reduce the level of safety even though the proposal as a whole may increase the level of safety.*]

Adoption of the proposal will increase safety relative to the current rule but is neutral given the current Generic Special Condition issued against all new airplane types for this safety concern.

9. Relative to current industry practice, does the proposed standard increase, decrease, or maintain the same level of safety? Explain. [*Since industry practice may be different that what is required by the FAR (e.g., general industry practice may be more restrictive), explain how each element of the proposed change to the standards affects the level of safety relative to current industry practice. Explain whether current industry practice is in compliance with the proposed standard.*]

The proposal maintains current practice.

10. What other options have been considered and why were they not selected? [*Explain what other options were considered and why they were not selected (e.g., cost/benefit, unacceptable decrease in the level of safety, lack of consensus, etc.)*]

The proposal was developed at the request of the FAA toAIA as a AIA/AECMA activity/project. The completion of this Industry Project led to a petition for rule making. The current proposal makes use of the AIA/AECMA proposal amended to incorporate some JAA and JAA-PPSG (Powerplant Study Group) comments.

11. Who would be affected by the proposed change?[*Identify the parties that would be materially affected by the rule change – airplane manufacturers, airplane operators, etc.*]

Airplane manufacturers, STC applicants for installation of a different engine type on an airplane, and engine manufacturers.

12. To insure harmonization, what current advisory material (e.g., ACJ, AMJ, AC, policy letters) needs to be included in the rule text or preamble? [*Does the existing advisory material include substantive requirements that should be contained in the regulation? This may occur because the regulation itself is vague, or if the advisory material is interpreted as providing the only acceptable means of compliance.*]

None. The added rule and supporting AC/J require no other changes. However, the preamble to the rule should clearly define that the AC contains interpretative material intended to establish the minimum safety standard.

13. Is the existing FAA advisory material adequate? If not, what advisory material should be adopted? [*Indicate whether the existing advisory material (if any) is adequate. If the current advisory material is not adequate, indicate whether the existing material should be revised, or new material provided. Also, either insert the text of the proposed advisory material here, or summarize the information it will contain, and indicate what form it will be in (e.g., Advisory Circular, policy, Order, etc.)*]

Not applicable – The new rule and advisory material are additive and do not interfere.

14. How does the proposed standard compare to current ICAO standard? [*Indicate whether the proposed standard complies with or does not comply with the applicable ICAO standards (if any).*]

Help! FAA/JAA to answer.

15. Does the proposed standard affect other HWG's? [*Indicate whether the proposed standard should be reviewed by other harmonization working groups and why.*]

No.

16. What is the cost impact of complying with the proposed standard? [*Is the overall cost impact likely to be significant, and will the cost be higher or lower? Include any cost savings that would result from complying with one harmonized rule instead of the two existing standards. Explain what items affect the cost of complying with the proposed standard relative to the cost of complying with the current standard.*]

Cost implications have already been addressed by the Generic Special Condition and given that the Special Condition was considered necessary the new rule and AC only clarify and standardize the requirements and no additional cost should be involved.

17. Does the HWG want to review the draft NPRM at "Phase 4" prior to publication in the Federal Register?

Yes.

18. In light of the information provided in this report, does the HWG consider that the "Fast Track" process is appropriate for this rule making project, or is the project too complex or controversial for the Fast Track Process. Explain? Explain. [A negative answer to this question will prompt the FAA to pull the project out of the Fast Track Process and forward the issues to the FAA's Rulemaking Management Council for consideration as a "significant "project.]

. *Yes*

Revision dated 8/12/99

AC / ACJ 25.903(e)

ENGINE RESTART CAPABILITY DEMONSTRATION FOR TRANSPORT CATEGORY AIRPLANES

1 - PURPOSE

This Advisory Circular (AC) provides information and guidance concerning a means, but not the only means, of compliance with section 25.903(e) of Part 25 of the Federal Aviation Regulations (FAR) which pertains to engine restart capabilities of Transport Category Airplanes. Accordingly, this material is neither mandatory nor regulatory in nature and does not constitute a regulation. In lieu of following this method, the applicant may elect to establish an alternate method of compliance that is acceptable to the Federal Aviation Administration (FAA) for complying with the requirements of the FAR sections listed below.

2 - SCOPE

This Advisory Circular provides guidance for a means of showing compliance with regulations applicable to engine restart capability in Transport Category Airplanes. This guidance applies to new airplanes designs as well as modifications to airplane or engine designs that would adversely affect engine restart capabilities.

3 - RELATED FARs and JARS

FAR Part 25, sections, 25.903(e), 25.1351(d), 25.1585(a)(3), JAR 25.903(e), JAR-E910, FAR 33.5(b)(3) and 33.89(a)(1).

4 - BACKGROUND

4.1 - Regulatory history

The inflight engine restart requirements for turbine powered airplanes are identified in §§§ 25.903 and 25.1351 and 25.1585 of the Federal Aviation Regulations (FAR). Sections 25.903 and 25.1585 requirements were developed from the engine inflight restart requirements of the earlier Civil Air Regulations (CAR) Part 4b. Paragraph 4b.401(c) required the ability for individually stopping and restarting the rotation of any engine during flight.

This intention was further incorporated into Part 25, specifically § 25.903(e), which requires 1) the ability to restart any engine during flight must be provided; 2) an altitude and airspeed envelope must be

established for inflight engine restarting, and each engine must have a restart capability within that envelope; and 3) if the minimum windmilling speed of the engines following the inflight shutdown of all engines, is insufficient to provide the necessary electrical power for engine ignition, a power source independent of the engine driven electrical power generating system must be provided to permit inflight engine ignition for restarting. In addition, Section 25.1351(d) requires demonstration that the airplane can be operated for 5 minutes following the loss of all normal electrical power (excluding the battery) with the critical type fuel (from the standpoint of flame out and restart capability) and with the airplane initially at the maximum certificated altitude. For airplanes equipped with Alternating Current (AC) powered fuel pumps that are powered from the engine electrical generators, this requirement has resulted in demonstration of the capability to windmill relight the engine while on suction feed with battery power for ignition. Relight of the engines has typically occurred at altitudes between 16,000 and 25,000 feet. In addition, as stated earlier in CAR 4b.742(d), the recommended procedures to be followed in restarting turbine engines in flight are to be described, including the effects of altitude.
This intention was also incorporated into Part 25, specifically § 25.1585(a), which states that information and instruction must be furnished, together with recommended procedures for restarting turbine engines during flight (including the effects of altitude).

There are no explicit inflight restarting requirements imposed on the engine in FAR 33 or JAR-E. Nevertheless there are requirements to define starting procedures (33.5(b), **33.89, E910) and to recommend an envelope (E910).**

Compliance with § 25.903(e) has been shown by establishing that adequate engine restart capabilities exist for the various engine types installed on transport category airplanes.
For example, many turbopropeller airplanes utilize electric starters that allow restart of the engine throughout the airplane airspeed and altitude flight envelope. Compliance is therefore easily shown by flight test demonstration of restart capability and analysis to show availability of electrical power for the starter. Turbo jet/turbo fan engines typically have windmill restart capability that is effective throughout a portion of the flight envelope, and utilize pneumatic starters to achieve restart throughout the remainder of the envelope. Compliance demonstration for these airplanes have included establishing both a windmill and a starter assist restart envelope. In several instances the windmill restart envelope has been limited to a small portion of the flight envelope. Applicants have utilized supplemental restart means, such as an essential APU installation to supply pneumatic power for restart to substantiate compliance.

Lack of an explicitely defined inflight restarting minimum standard has resulted in wide variations in the restart capabilities of transport category airplanes. Some newer technology engines require several minutes at airspeeds above 250kts to windmill restart.

In addition, some turbopropeller engines with free turbines have limited or no windmill restart capabilities within the normal airplane operating envelope. On certain airplane types that are not equipped with means to assist restart, reduced engine restart capabilities could result in an unsafe condition following an all-engine flame out event at mid to low altitudes.The altitude loss required to obtain sufficient airspeed for a windmill restart, in conjunction with the associated long restart times, may not allow restart prior to reaching ground level.

4.2 - Service History

Since the beginning of aviation, all-engine power loss incidents have occurred. Incidents have been reported on almost every airplane type for various reasons such as fuel mismanagement, loss of electrical power, crew error, mis-trimming of engine idle setting, fuel nozzle coking, volcanic ash encounters, and inclement weather. The FAA has determined that the all-engine power loss event must be considered in airplane design.

Section 25.671 requires that the flight controls be designed such that control of the airplane can be maintained following the loss of all engine power. The service experience supports the position that suitable engine restart capability must be available following the loss of all engine power to avoid an unsafe condition.

4.3 - Industry Restart Data

Industry historical records contain many (at least 30 events in the period 1982 up to 1993) multiple engine power loss events.

These records show all-engine power loss events that jeopardized continued safe flight have occurred (over the altitude range) for the following reasons :

Weather	(Low Altitude to FL410)
Volcanic Ash	(FL370, FL330, FL250, low altitude possible)
Crew error	**(FL030 to FL410)**
Compressor Surge	(Takeoff to cruise altitude)
Maintenance Error	(Takeoff to cruise altitude)
Other/Unknown	(Takeoff to cruise altitude)

It does not appear that it is possible to define in advance all of the potential causes for critical power loss and/or preclude their occurrence. Thus it is necessary to define what engine restart capabilities are required to maintain the current level of safety.

5 - DEFINITIONS

a) Relight : The combustor lights off and sustains combustion.

b) Restart : The engine has accelerated to stabilized flight idle.

c) Windmill Relight Envelope : The portion of the airplane airspeed/altitude envelope where the engine is capable of being restarted without starter assistance.

d) Power Assisted Relight Envelope : The portion of the airplane airspeed/altitude envelope where the engine requires starter assistance to achieve restart.

e) Auto Ignition System : A system that automatically activates the engine ignitors if pre-determined conditions apply (e.g., ice detectors indicate icing conditions, flaps are configured for approach/landing, etc.).

f) Auto Start System : A system that monitors engine parameters during starting and automatically sequences fuel flow accordingly. It may include logic protecting against turbine temperature limit exceedance and sub-idle stall, among other features.
It reduces pilot work load by eliminating the need to manually turn fuel on at a given core speed and to monitor the speed/turbine temperature relationship during the start.

g) Auto Depulse Logic/Stall Recovery Logic : Logic incorporated into the engine control that momentarily shuts off fuel flow to clear an engine stall.

h) Auto-Relight : A feature which monitors the operation of the engine to attempt to recover an engine flameout. In its most basic form, it is equivalent to automatically selecting continuous ignition. When the engine control senses that an engine has flamed out (by rotor speed decay, a drop in combustor pressure, or other means), it turns on the ignitors.
Auto-relight typically reacts much more quickly to a flame out than a pilot could.

The effects of the loss of engine power from one, multiple and all engines must be considered. However, the loss of all engines generally determines the most stringent requirements in terms of restart capability, and the intent of the regulation will be satisfied by addressing this critical case.

In order to confirm that engine restarting can be achieved, in circumstances where all engines run down or are shut down, the applicant will be expected to show by test or analysis supported by tests that sufficient power/thrust can be restored to enable the airplane to achieve level flight without excessive loss of altitude.

Four conditions are to be addressed :

1) Shut down from take off/climb power with pilot recognition time delay based on analysis of indications (inherent or dedicated indicators) to the flight crews (Pilot recognition time has typically ranged from 5 to 15 seconds based on service data).
Acceptable means of compliance include rapid relight procedures or starter assistance from an external power source. The altitude loss between initiating the restart and achieving level flight should not exceed 2500ft.

2) An engine should be able to be restarted at a minimum altitude of 15,000ft from a shut down at typical descent speed at 20,000ft or above.

3) The engine should be able to be restarted with an altitude loss not exceeding 5000ft from a power loss occurring between 10,000 and 20,000 feet.

   The aircraft speed at the time of power loss should be representative of the normal flight profile (climb or descent) in this altitude range for the flight phase considered.

4) Flame out or shut down from descent power below 10,000ft with a delay in crew action based on indications (inherent or dedicated indicators) to the flight crew of all engine power loss.
A 30 second crew recognition time should be used if no dedicated indication is provided.
Crew Recognition Time may be shortened based upon dedicated indications that engines have flamed out or rolled back to sub-idle, as well as aircraft design features which minimize the potential for inadvertent shutoff. Other factors which may be considered in the crew recognition time evaluation include automatic relight and automatic sub-idle stall recovery systems.
The initial airplane speed that should be used for the all-engine out restart evaluation is 1.45V stall (clean configuration) of the maximum landing weight of the aircraft.
Acceptable means of compliance include rapid relight, starter assistance from an external source and stabilized windmill start. The airplane should not lose more than 5000 feet altitude between initiating restart procedures and achieving level flight. In addition, the maximum aircraft speed to achieve the restart should not exceed 250kts.

These compliance guidelines are summarized in a tabular form here below :

	I TAKE OFF	II HIGH ALTITUDE	III CLIMB/DESCENT	IV LOW/SLOW
INITIAL ALTITUDE	Approved Takeoff Altitude Range	20 kft +	10 to 20 kft	10kft to landing

8.6 - Additional compliance demonstrations

As a complement to the compliance demonstrations carried out to establish and validate the declared airstart envelope, the capability to restart the engine should be demonstrated in the following particular cases :

a) Restart after engine cold-soak

Some restarts should be carried out within the declared restart envelope after shut down periods of 5 minutes and 15 minutes.

b) Immediate restart after shut down from high power

- The capability to immediately restart the engine after a shut down from max climb power following a take-off should be demonstrated.

- If the means of compliance is a quick relight procedure, the fuel interruption should last typically 5 to 15 seconds depending on indications available to the crew (as stipulated in section 7), and the engine should relight and reaccelerate to its original power without any crew actions other than selecting ignition and fuel.

c) Restart after suction feed flameout

For airplanes equipped with AC powered booster pumps, the effect of the loss of all normal AC power should be tested.

The test should be conducted using the worst case fuel from an engine flame-out standpoint.
If the fuel volatility is greater than that of Jet A/Jet A1, the fuel should be preheated in mass such that the fuel temperature in the aircraft tank is at least 110° F after refueling.

The capability to restart engines should be demonstrated when the suction feed flame-out occurs at the maximum cruise altitude, and also at the maximum suction feed climb altitude if no alert is provided to deter the crew from climbing above it when operating in gravity feed conditions.

For the maximum cruise altitude case, the test should consist of a straight climb to the aircraft ceiling altitude, where the loss of AC power will be simulated for one engine. If flame-out occurs, the restart of the engine should be attempted with the aircraft configured to be representative of an all engine flame-out condition.

For the suction feed climb case, the loss of AC power should be simulated for one engine immediately after take-off and a continuous climb performed until the engine flames out. The restart should be attempted with the aircraft configured to be representative of an all engine flame-out condition.

For both cases, a successful restart should be achieved prior to reaching 10000ft if the fuel volatility is greater than that of Jet A/Jet A1, or 15,000ft with all others.

ALTITUDE LOSS *	2500 ft	Relight by 15kft	5000 ft	5000 ft
MAX ALLOWABLE AIRSPEED	N/A	N/A	N/A	250 KTS (based on max airspeed below 10 kft)
INITIAL AIRSPEED	***Minimum Clean Configuration*** speed or 250 kts **	Typical descent speed	Normal flight profile (climb or descent speed)	1.45 V stall (clean airplane config.)
RECOGNITION TIME	typically 5 to 15 seconds	N/A	N/A	30 seconds or less depending on indications
ACCEPTABLE MEANS OF COMPLIANCE	Rapid relight or assisted relight from an external source	Stabilized windmill start or starter assist from an external source	Stabilized windmill start or starter assist from an external source	Rapid relight, starter assist from an external power source or stabilized windmill start

* Note Altitude loss measured from initiation of restart procedure
** Note – the lesser of the two speeds

8 - COMPLIANCE DEMONSTRATION

8.1 - General

The restart envelope and procedures declared by the applicant are intended to fulfill the guidelines specified in section 7.

The declared restart envelope will generally consist of several zones.

- One zone where the engine is rotated by windmilling at a sufficiently high RPM to achieve a successful restart. This zone may be subdivided into a stabilized windmill restart envelope and a spooling – down restart envelope (rapid relight).
- Another zone where the engine is rotated with the assistance of a starter to a sufficiently high RPM to achieve a restart.

Each zone must be identified in the Airplane Flight Manual. Sufficient tests must be carried out in each zone to validate it reliably.

8.2 - Demonstration procedure for stabilized windmill airstarts

- Tests should be conducted so that the windmill speed of the test engine is fully stabilized when the target altitude and aircraft speed are reached.
- The engine fuel feed system, hydraulic system and electrical system should be configured to be representative of an all engine flame-out condition.
- The time to relight should not exceed 30 seconds and the spool-up time from relight to idle should not exceed 90 seconds. A longer spool-up time may be acceptable if a positive indication is available to the crew that the start is progressing normally. However the altitude loss associated with the total restart time (from fuel on to idle) in an all engine flame-out condition should not exceed 5000ft, when the restart is initiated at or below 20000ft (as stipulated in section 7).

8.3 - Demonstration procedure for spooling-down windmill airstarts (rapid relight)

- The declared rapid restart envelope should be based on a fuel interruption of not less than 30 seconds. A shorter time may be acceptable if a dedicated engine failure annunciation is provided to the crew.

- Tests should be conducted with the engine initially stabilized at idle. The engine should relight and accelerate to idle without requiring any crew actions other than selecting ignition and fuel.

- The same conditions as in § 8.2 above should be observed for the engine fuel feed system, hydraulic system and electrical system.

- The same criteria as in § 8.2 should be used for times to relight and spool-up.

8.4 - Demonstration procedure for starter-assisted airstarts

- Tests should be conducted so that the windmill speed of the test engine is fully stabilized when the target altitude and aircraft speed are reached.

- The engine fuel feed system, hydraulic system and electrical system should be configured to be representative of the condition of the airplane for the case considered.

- The same criteria as in § 8.2 should be used for times to relight and spool-up.

8.5 Demonstration procedure for APU assisted engine airstarts

If an APU assisted engine airstart is used for compliance with any of the section 7 restart conditions, the following guidelines should be followed:

- the APU installation should be certified as "essential"
- a minimum of a 95% APU start reliability must be demonstrated by test considering:
    i) maximum APU cold soak appropriate for restart condition being addressed (note that the APU coldsoak associated with the maximum airplane range should be considered for the high altitude cruise condition II and the descent condition IV)
    ii) a maximum of two APU start attempts shall be allowed for each start condition
    iii) continuous APU operation throughout the affected flight regime may be used in lieu of demonstrating APU inflight start reliability
- APU start time should be considered in the airplane altitude loss calculation
- In order to maintain the APU's demonstrated start reliability after the airplane is introduced into service, the airplane and APU manufacturer should develop a maintenance program for the APU installation. This maintenance program should include general APU maintenance tasks, periodic checks of the APU's inflight starting capability and a post-maintenance inflight start verification. The critical maintenance tasks, start functional checks, as well as their associated time intervals should be mandated. Consideration of including these items as Certification Maintenance Requirements should be given.
- if an APU assisted engine start is used for complying with the low altitude conditions I or IV (takeoff and descent/landing), then the airplane should incorporate logic which automatically recognizes the all engine powerloss condition and automatically restarts the APU. Further, consideration should be given to also automatically reconfigure the airplane pneumatic and/or electrical system to minimize the crew workload associated with achieving main engine restart during these critical low altitude conditions.